DOCUMENT RESUME

ED 465 606 SE 066 328

AUTHOR Sterling, Donna R.
TITLE Strategies Enabling Teachers To Critically Analyze Learning and Teaching.
PUB DATE 2002-01-00
NOTE 15p.; In: Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science (Charlotte, NC, January 10-13, 2002); see SE 066 324.
AVAILABLE FROM For full text: http://aets.chem.pitt.edu.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Elementary Secondary Education; *Faculty Development; *Mathematics Curriculum; *National Standards; *Science Teachers

ABSTRACT

This paper shares the findings from four years of Eisenhower-funded research which identified conceptual obstacles and enabling strategies for interdisciplinary teams of grade 4-12 teachers to develop and implement integrated standards-based science and mathematics teaching and assessment plans in their classes that are effective in helping students learn. The program provided professional development for 80 teachers in 37 teams of science and mathematics teachers in 12 rural and urban school districts to develop and implement integrated teaching and assessment plans that follow the National Science Education Standards, Principles and Standards for School Mathematics, Benchmarks for Science Literacy, and Standards of Learning for Virginia Public Schools. Though the research investigated teaching and assessment, this paper focuses on strategies to enhance the teachers' critical analysis skills for assessing student learning. (Contains 46 references.) (Author/MVL)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 465 606

Strategies Enabling Teachers to Critically Analyze Learning and Teaching

by
Donna R. Sterling

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

P. Rubba

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

1

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

SE064328

BEST COPY AVAILABLE

STRATEGIES ENABLING TEACHERS TO CRITICALLY ANALYZE LEARNING AND TEACHING

Donna R. Sterling, George Mason University

This paper shares the findings from four years of Eisenhower funded research which identified conceptual obstacles and enabling strategies for interdisciplinary teams of grade 4-12 teachers to develop and implement integrated standards-based science and mathematics teaching and assessment plans in their classes that are effective in helping students learn. The program provided professional development for 80 teachers in 37 teams of science and mathematics teachers in 12 rural and urban school districts to develop and implement integrated teaching and assessment plans that follow the *National Science Education Standards* (National Research Council, 1996), *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000), *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), and *Standards of Learning for Virginia Public Schools* (Board of Education Commonwealth of Virginia, 1995). Though the research investigated teaching and assessment, this paper focuses on strategies to enhance the teachers' critical analysis skills for assessing student learning.

As teachers change the way they teach to meet new national and state standards, they need to also change the way they plan for teaching and assessment of student understanding. The purpose of this research was to identify conceptual factors that limit teachers' ability to successfully develop and implement effective teaching and assessment plans for their students. Once limiting factors were identified, enabling strategies were developed. The main areas for teacher professional development during the summer and implementation year were standards-based integrated science and mathematics subject matter and pedagogy, planning for teaching and assessment, and critically analyzing student learning (Scantlebury, Boone, Kahle, & Fraser, 2001). Though the science theme varied from year to year, an underlying focus on data analysis and experimental design remained. This presentation will focus on the support scaffolding that enabled teachers to more effectively critique their students' learning.

This study has implications for K-12 teacher professional development as we seek to help individual teachers and teams of teachers plan for standards-based teaching and assessment. As obstacles are identified and enabling strategies developed, teachers will be better able to plan and teach in ways called for in the state and national standards for science and mathematics.

SE064328

Theoretical Underpinnings

The study grew out of the recognition of the increasing importance for universities and schools to work together to support the learning and teaching of science and mathematics. It also grew out of the need to help teachers develop a vision of the kind of teaching and assessment called for in the national standards and the need to implement this type of learning and assessment in their classes (Anderson & Helms, 2001; Kahle, Meece, & Scantlebury, 2000; Lynch, 1997; Sterling, 1997, 2000, 2001; Sterling, Olkin, Calinger, Howe, & Bell, 1999).

Since few changes usually take place as a result of professional teacher development (Guskey, 1995), we built into the program characteristics of "best practices" and "best of the best" for exemplary teacher professional development programs including a thematic design, supportive infrastructure, and utilization of evaluation (Ruskus, Luczak, & SRI International, 1995). A systemic approach was used that aligned curriculum, instruction, and assessment with local, state, or national standards and recruited teams of teachers from the same school and school division with the support of that division (Scantlebury et al., 2001). Additionally we focused on collaboration and follow-up (Gallagher, 1996; Ruskus, et al., 1995). Research suggests that meaningful collaboration facilitates educational reform (Anderson & Helms, 2001; Fullan, 1991; Keys & Bryan, 2001) and collaborative work cultures enhance student learning (Crawford, Kelly, & Brown, 2000; Newmann & Wehlege, 1995).

To enhance the daily professional development environment of the summer workshops, many aspects of collaboration were built into the program (Keys & Bryan, 2001; Sweeney, Bula, & Cornett, 2001; Van Driel, Beijaard, & Verloop, 2001). Social learning theory suggests the importance of observing and modeling behaviors, attitudes, and emotional reactions of others as part of self-efficacy (Bandura, 1977). Therefore staff members were carefully chosen and provided with their own professional development training so that they became a team immersed in the projects culture. Vygotsky's (1986) social development theory suggests that social interaction plays a pivotal role in cognitive development with peer collaboration exceeding what can be learned alone. Team problem solving and planning were an integral part of the program. According to Bruner (1960, 1990), learning is an active process where the learner constructs new knowledge by discovering principles themselves under the guidance of an instructor. Therefore instruction encouraged active dialog to uncover the structure and organization of new information in order for the learner to go beyond the information given (van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). Experiential learning situations were established through classroom experiences where the learners became personally involved in self-initiated activities when they designed and conducted their own research

investigations (Rogers, 1969). Cross (1981) emphasizes the importance for adult learning to be self-directed and problem-centered where they have as much choice as possible. Teacher teams were given the flexibility to adapt all assignments and research to their own schools and working situations. The perception of self-efficacy enhances cognitive development (Bandura, 1993, 1997).

Initially the study focused on the scaffolding teachers needed to plan and teach standard-based science and mathematics. During this time, we realized that until teachers focused more on assessing student understanding few gains were likely to be made (Brown & Shavelson, 1996; Champagne, Lovitts, & Calinger, 1990; Kyle, 1997). While focusing on assessment, we realized that many teachers needed to be more critical about their students' learning and their teaching. Our study has now been extended to focus on enhancing the teacher's ability to critically evaluate learning and teaching.

The immediate impetus for focusing on critical analysis of learning and teaching by teachers occurred when a team of teachers, who were reporting on a hands-on lesson where learning was not likely to have taken place, justified the success of their lesson by claiming their students had fun. Though fun is a desirable outcome from learning, it is not a replacement for learning. This particular team of teacher did not seen to have the knowledge and skills to critically analyze success in the classroom. Though many teachers are naturally reflective and critical about student learning, many are not. It became our goal to help all teachers critically analyze learning and teaching for the purpose of continually enhancing learning.

Design and Procedure

Program Design

Structurally the program was set up to include teams of teachers collaboratively studying over an extended time period (Kahle, Meece, & Scantlebury, 2000; U.S. Department of Education, 1999; Van Driel et al., 2001). The program had an initial concentration of study and planning time for teachers in the summer followed by six to nine months of implementation, analysis, and sharing of findings during the academic year (Anderson & Helms, 2001).

The program was designed to provide participating teachers with professional development necessary to enable them to develop and implement integrated, hands-on, inquiry-based science and mathematics teaching and assessment plans (Parke & Coble, 2001). During the summer workshops the teacher teams focused on developing integrated teaching plans that included the basic elements of experimental design and data analysis (Cothron, Giese, & Rezba, 2000; Virginia Department of Education, 2001). During the academic year the teachers focused on

implementing their plans and assessing their students growing understanding with support from their team members, other teams, and the instructional leadership team (Anderson & Helms, 2001; Sweeney et al., 2001; Van Driel et al., 2001).

Leadership Team

The first phase of the program was to develop a leadership team that co-planned and taught the summer workshops and follow-up sessions. The team consisted of university faculty from science, mathematics, and education and teacher leaders from the different participating school divisions who were specialists in science or mathematics. Leadership skills were developed through increased knowledge of integrated science and mathematics gained by working with an interdisciplinary team during the planning and piloting process, critical analysis of student-centered teaching strategies and assessment practices, development and implementation of workshop plans, peer teaching and mentoring, and reflection and evaluation on every aspect of the program.

Teacher Teams

For this project, the ideal team was 2-3 teachers from the same school teaching the same grade level who could plan together. When this was not possible, teachers were allowed to choose to work with teachers from different schools but all at the same grade level or with teachers from different grade levels at the same school. Though we were not assessing effectiveness of team configuration, all arrangements appeared to enhance teachers' experiences. Teacher connectivity and camaraderie appeared to be more significant than team configuration. The teacher teams created teaching plans that incorporated multiple forms of diagnostic, formative, and summative assessment to monitor student learning in their classes (Bell & Cowie, 2001; Treagust, Jacobowitz, Gallagher, & Parker, 2001). The research task for teachers was to identify a content standard and prove to their peers through assessment of understanding that their students had mastered the standard. If the standard was not mastered, they were to identify their students' misunderstandings or misconceptions and their plans for enhancing understanding.

Research Methodology

Using a constant comparative process (Glaser, 1978; McMillan & Schumacher, 1984), data collected through surveys, interviews, focus groups, observations, and analysis of artifacts identified obstacles the teacher teams needed to overcome in developing integrated, inquiry-based science and mathematics teaching and assessment plans. A leadership team of scientists, mathematicians, and educators conducted the on-going formative research. The team analyzed the data on a daily basis during the summer program. This staffing arrangement

provided triangulation among the staff observations and interviews where staff members independently identified problems that were in most cases observed by others.

Through a continuous improvement model, support scaffolding was developed that enabled teachers to effectively conduct research on their students understanding (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). The support scaffolding provided teachers with a simple way to assist in interpreting the complexity of teaching and constructing plans and hence assisted in the change process (Anderson and Helms, 2001; Barnett & Hodson, 2001).

Findings

Scaffolding for Planning

The scaffolding that enables teachers to develop a vision of the kind of inquiry-based teaching and assessment called for by the standards and to effectively plan to create this type of teaching in their classroom fell into two categories - conceptual organizers and guided planning. Conceptual organizers in the form of graphic organizers proved to be especially helpful and were created to guide planning for teaching, assessment, and critical analysis.

Obstacles and Enabling Strategies for Teaching and Assessment

It became apparent that when teachers were developing their own teaching plans that were not based around a core set of materials such as a textbook, they were left with an organizing structural void. To fill this void, an inquiry-based conceptual organizer, a type of advanced organizer, provided an organizing structure/scaffolding around which to base teaching plans (Sterling, 2000). The inquiry hierarchy provided structure to both subject matter and pedagogical strategies. The inquiry hierarchy is similar to backmapping used to develop *Benchmarks for Science Literacy* (AAAS, 1993) in that it shows the relationship of unit science concepts. It is also similar to a problem-based unit that has a question guiding the instruction.

Likewise it was found that teachers also needed an organizational structure around which to develop their assessment plans. The assessment timeline conceptually organized a process for teachers to identify and monitor student learning (Sterling, 2001). By developing a before, during, and after paradigm of diagnostic, formative, and summative assessment, the teachers were able to embed assessment in their teaching. The teachers found that when they embedded assessment routinely as part of their instruction, they became more effective at assessing their students understanding of science and in turn informing their instruction (Treagust et al., 2001).

Beyond the conceptual organizers, guided planning provided additional structure for the teachers that enabled them to create teaching and assessment plans which they could conceptually defend to their peers. The guided planning was a sequential series of decisions made by the teachers about the teaching plan or assessment plan they were developing, followed by an analysis of their decisions made from different perspectives.

Obstacles and Enabling Strategies for Student Understanding

While most teachers easily focused on assessing student understanding, peripherally related issues such as fun and active student involvement sidetracked some. Both fun and active student involvement are desirable outcomes. However, they may not be directly related to developing student conceptual understanding.

To help teachers critically evaluate learning, a critical analysis taxonomy was developed showing a hierarchy of levels for analysis and evaluation (Figure 1). The taxonomy provides a structure for the purpose of continuous improvement for the teachers to evaluate effective learning and teaching. The taxonomy progresses from analyzing the effective aspects, to identifying the weaknesses, to suggestions for improvement, to extensions or links to other information. Using the taxonomy provided teachers with a conceptual framework for the evaluation process that delved at successively deeper levels of evaluation.

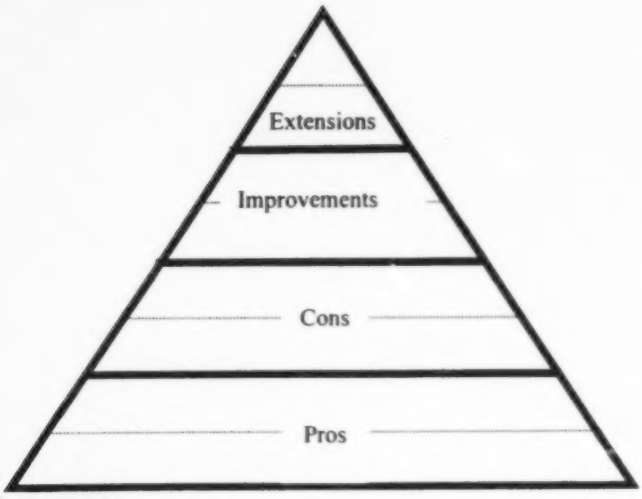

Figure 1. Critical analysis taxonomy.

The critical analysis taxonomy also guided the teachers analysis when they implemented their teaching and assessment plans. By having teachers share all the levels of the critical analysis hierarchy, they celebrated their successes and group problem solved areas that needed further development. They became a team of professionals working together.

Critical Analysis Taxonomy

The critical analysis taxonomy provided a mental model for teachers to analyze student understanding. The taxonomy, a graphic organizer, combined the elements of a hierarchy with the need for depth of multiple formats of analysis. The reason for the hierarchy aspect was because the multiple levels for evaluation are based on a continuous improvement model and the research of Bloom (1956) and others that classifies thinking in a six level cognitive hierarchy from low to high level and that shows that people understand at many different levels. The hierarchy is also based on motivation systems theory and the need for positive regard for success (Ford, 1992). Continuous improvement is the goal but acknowledging what is working well is important so that it continues to be repeated. The continuous improvement model has the focus on improvement and not change for change sake. Therefore, it is important to include what is working so that it is not changed but continued.

The critical analysis taxonomy provides a basis for evaluating most things and can be used by teachers as well as students. It could apply to a lesson being taught by a teacher or to evaluating an essay or poster by students. For a continuous improvement model the hierarchy builds from compliments, to criticism, to suggestions for

improvement, to extensions. Therefore it could be viewed as a cycle or spiral with each round of analysis informing the teacher and student about the level of understanding or lack of understanding. This in turn would inform instruction and learning, and focus on improvement.

All levels of the hierarchy can be subdivided into two groups, critical analysis/comments that are peripherally related or that focus on core elements of effectiveness for the work being evaluated. Comments that are central to the effectiveness of the work being evaluated are the target for each level. However, by including peripherally related comments, a focus can be placed on honing in on core elements, but also acknowledging peripherally related comments and analysis.

Pros

The base of the hierarchy is identifying positive or successful aspects of the work being evaluated. Most people find it easier to give compliments than to criticize. An example of the two levels within the pros category when evaluating a teaching activity are comments about peripheral issues such as students having fun as compared to comments about student learning. Though having fun is desirable, it is not usually the central purpose for an activity.

Cons

Identifying aspects that are not working or are only partially working is the next step and a prerequisite to improving. It is generally more difficult for people to be forthcoming when analyzing what is not working than what is working because of values associated with lack of success. Therefore we deepened the "cons" part of the analysis to a problem-solving/data analysis paradigm where problems are solved (Cothron, Giese, & Rezba, 2000; Gabel, 2002) (see Figure 2). Analysis of errors of understanding is a cyclic process that starts with identifying errors and looking for patterns among identified errors. Analyzing reasons for errors and clarifying as needed by gathering more data about what led to errors enables teachers or students to plan for remediation. After remediation, the cycle starts again with identifying evidence of understanding or errors in understanding to determine if remediation has been successful.

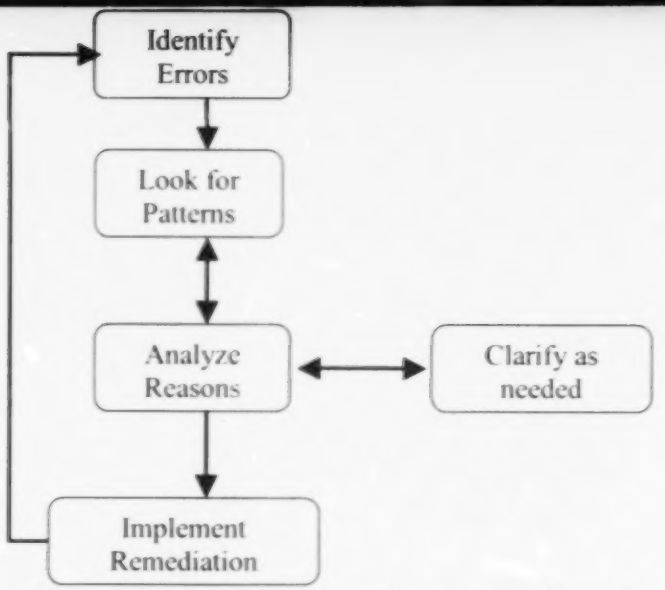

Figure 2. Error analysis.

Establishing a safe and supportive environment that focuses on continuous improvement and rewards honest reflection is crucial to encourage sharing especially of less than stellar performance by students or teachers. As part of the sharing process, teachers shared samples of student work. In most cases they shared three samples, one each from the top, middle, and bottom third of their class. Inquiring into your own practice and sharing about research findings and dilemmas is part of the new inquiry group paradigm for professional development (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

Improvements

After identifying what is not working, suggesting possible solutions to problems or ways to make something more effective is the next level.

Extensions

Extensions are ways that the work being assessed can be connected or extended to make it more meaningful. It tends to be value neutral and thus brings the focus back to quality teaching and assessment at all levels.

The taxonomy proved to be most helpful in stretching teachers to go beyond accepting the status quo to improving learning and teaching. The teachers also found that the taxonomy could be used with students to help them with evaluation of their own and other students' work.

Conclusion

This study identified conceptual obstacles for standards-based teaching and assessment and developed support scaffolding that enabled teachers to understand and accommodate into their teaching style a student-centered approach to assessment. The scaffolding included an assessment timeline and critical analysis taxonomy that

conceptually organized the assessment process and a series of assessment analyses that focused on the effectiveness of learning and assessment strategies.

By conducting research on their own students' understanding, the teachers appear to critically analyze the teaching and learning process. The teachers found that when they embedded assessment routinely as part of their instruction, they became more effective at assessing their students understanding of science during the teaching process especially when they used multiple forms of assessment.

As new ways of teaching and assessing learning challenge traditional methodology, teachers need time to work through the conceptual change process. As the teachers are introduced to new methodologies and develop a new understanding of effective science teaching, they require multiple experiences that challenge their understanding of learning. A simple conceptual paradigm and a series of experiences that assists the teachers in investigating overtime the new strategies at ever increasing depths helps teachers to progress through the change process.

By using the critical analysis taxonomy and conducting research on their own students understanding, most teachers appear to be able to critically analyze the teaching and learning process for their students. Our research identified conceptual obstacles for creating and evaluating standards-based teaching and assessment and developed scaffolding that enabled teachers to understand and accommodate into their teaching style a student-centered approach to hands-on, inquiry-based teaching and assessment that led to assessing and extending student conceptual understanding.

References

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press, Inc.

Anderson, R. D., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching, 38*, 3-16.

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117-148.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman and Company.

Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. *Science Education, 85*, 426-453.

Bell, B., & Cowie, B. (2001). The characteristics of formative assessment in science education. *Science Education, 85*, 536-553.

Board of Education Commonwealth of Virginia. (1995, June). *Standards of Learning for Virginia Public Schools*. Richmond, VA: Virginia Department of Education.

Brown, J. H., & Shavelson, R. J. (1996). *Assessing hands-on science*. Thousand Oaks, CA: Corwin Press, Inc.

Bruner, J. (1960). *The process of education*. Cambridge, MA: Harvard University Press.

Bruner, J. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Champagne, A. B., Lovitts, B. E., & Calinger, B. J. (Eds.). (1990). *Assessment in the service of instruction*. Washington, DC: American Association for the Advancement of Science.

Cothron, J. H., Giese, R. N., & Rezba, R. J. (2000). *Students and research*. Dubuque, IA: Kendall/Hunt Publishing.

Crawford, T., Kelly, G. J., & Brown, C. (2000). Ways of knowing beyond facts and laws of science: An ethnographic investigation of student engagement in scientific practices. *Journal of Research in Science Teaching, 37*, 237-258.

Cross, K. P. (1981). *Adults as learners*. San Francisco: Jossey-Bass.

Ford, M. E. (1992). *Motivating Humans*. Newbury Park, CA: Sage Publications.

Fullan, M. G. (1991). *The new meaning of educational change*. New York: Teachers College Press.

Gabel, D. (2000). Problem Solving in Chemistry. Online research of the National Association for Research in Science Teaching. [Online]. Available: http://www.educ.sfu.ca/narstsite/research/problem.htm.

Gallagher, J. J. (1996). Implementing teacher change at the school level. In *Improving teaching and learning in science and mathematics*, edited by D. F. Treagust, R. Duit and B. J. Fraser. New York: Teachers College Press.

Glaser, B. G. (1978). *Theoretical sensitivity: Advances in the methodology of grounded theory*. Mill Valley, CA: Sociology Press.

Guskey, T. R. (1995). Professional development in education: In search of the optimal mix. In *Professional development in education: New paradigms and practices*, edited by T. R. Guskey and M. Huberman, 114-131. New York: Teachers College Press.

Kahle, J. B., Meece, J., & Scantlebury, K. (2000). Urban African-American middle school science students: Does standards-based teaching make a difference? *Journal of Research in Science Teaching, 37,* 1019-1041.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38,* 631-645.

Kyle, W. C., Jr. (1997). Assessing students understanding of science. *Journal of Research in Science Teaching, 34,* 851-852.

Lynch, S. (1997). Novice teachers' encounter with national science education reform: Entanglements or intelligent interconnections? *Journal of Research in Science Teaching, 34,* 3-17.

McMillan, J. H. & Schumacher, S. (1984). *Research in education.* Boston: Little, Brown and Company.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics.* Reston, VA: author.

National Commission on Mathematics and Science Teaching for the 21st Century. (2000) *Before it's too late.* Washington, DC: U.S. Department of Education.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

Newmann, F., & Wehlage, G. (1995). *Successful school restructuring.* Madison WI: Center on Organization and Restructuring of Schools.

Parke, H. M., & Coble, C. R. (2001). Teachers designing curriculum as professional development: A model for transformational science teaching. *Journal of Research in Science Teaching, 38,* 773-789.

Rogers, C. R. (1969). *Freedom to learn.* Columbus, OH: Merrill.

Ruskus, J., Luczak, J., & SRI International. (1995). *Best practice in action: A descriptive analysis of exemplary teacher enhancement institutes in science and technology.* Washington, DC: SRI International.

Scantlebury, K., Boone, W., Kahle, J. B. & Fraser, B. J. (2001). Design, validation, and use of an evaluation instrument for monitoring systemic reform. *Journal of Research in Science Teaching, 38,* 646-662.

Sterling, D. R. (1997). *Stages of conceptual change that enable teachers to adopt a student-centered approach to hands-on, inquiry-based teaching.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Oak Brook, IL, March.

Sterling, D. R. (2000). *Strategies enabling interdisciplinary teacher teams to develop and implement standards-based teaching plans.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA, April.

Sterling, D. R. (2001). *Strategies enabling collaborative teacher teams to assess student understanding of science.* Paper presented at the annual conference of the National Association for Research in Science Teaching, St. Louis, MO.

Sterling, D. R., Olkin, A. H., Calinger, B. J., Howe, A. C., & Bell, J. A. (1999). Project Alliance: Enhancing Science and Technology Instruction in the Middle Grades through Interdisciplinary Team Planning and Teaching. *Online Monograph of the American Association for the Advancement of Science*. [Online]. Available: http://ehrweb.aaas.org/ehr/projectalliance/

Sweeney, A. E., Bula, O. A., & Cornett, J. W. (2001). The role of personal practice theories in the professional development of a beginning high school chemistry teacher. *Journal of Research in Science Teaching, 38,* 408-441.

Treagust, D. F., Jacobowitz, R., Gallagher, J. L., & Parker, J. (2001). Using assessment as a guide in teaching for understanding: A case study of a middle school science class learning about sound. *Science Education, 85,* 137-157.

U.S. Department of Education (1999). *Designing effective professional development: Lesson from the Eisenhower program*. (Document No. 99-3) Washington, DC.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38,* 137-158.

van Zee, E. H., Iwasyk, M. Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching, 38,* 159-190.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: MIT Press.